Thou mental moral orb, thou new, indeed new, spiritual world,
The Present holds thee not—for such vast growth as thine,
For such unparalleled flight as thine, such brood as thine,
The Future only holds thee and can hold thee.*

G. BROWN GOODE.
U. S. NATIONAL MUSEUM.

LEGAL UNITS OF ELECTRIC MEASURE.

IT will, doubtless, be interesting to all physicists, as well as to many in other departments of science, to know of the legalization by Act of Congress, within the last six months, of units of electrical measure. It is not necessary in these columns to go into an exposition of the necessity for such action on the part of the Government, nor to refer to the enormous amount of capital invested in the manufacture of instruments, devices and machinery, the sole object of which is the conversion of some form of energy into electricity and the reconversion of electricity into some form of energy. The measurement of the enormous quantities of electricity that have within the last decade been produced and thus converted has, up to a recent date, in all cases depended upon the conventional acceptance of units of measure which have for many years been in use among scientific men, and which originated in the necessity for such units of measure in scientific investigations. It is always worth while to note, however, that the great simplicity and perfection of electrical measurement is due to the fact that the science of electricity preceded the art of its utilization. In this respect electrical engineering has a very decided advantage over all other branches of engineering, for in all others the art preceded the science, and the science, therefore, was obliged to build itself upon the crude and mostly unphilosophical principles that developed in the art.

*Whitman, *Leaves of Grass.*

The fundamental units of electrical measure, namely, the ohm, the ampere and the volt, have been in use among scientific men, to the exclusion of all others, for more than a decade, related as they are to the fundamental units—length, mass and time, which are admirably adapted for use as the basis of all electrical metrology. It has, however, long been recognized that much inconvenience was caused in electrical discussion by the lack of a few additional units, the use of which would greatly facilitate mathematical calculations and numerical statements. The literature of the subject has abounded, during the past ten years, with suggestions as to these additional and desirable units of measure, and various writers have, from time to time, adopted such as seemed to be necessary for their own use, even giving them such values and such names as were best in their judgment. It was evident, therefore, that to prevent confusion in electrical nomenclature it was desirable to have an international agreement as to these units, their value, their number and their names; the demands for this have grown very extensive in the last few years, the result having now been reached in the passage, by Congress, of a law which seems to define and settle these questions as far as the United States Government is concerned.

All readers of this journal are, doubtless, familiar with the fact that as early as 1881 an electrical convention, or congress, was held in Paris for the purpose of trying to agree upon definitions of the fundamental units of electrical measure and their material representations, in cases where material representations were possible. After much discussion, and not without very considerable opposition, there was proposed at that time a material representation of the ohm which was known to be somewhat in error. The real ohm must always be that defined by the Committee of the British Association

for the Advancement of Science, and any material representation which may be adopted should only be considered as an approximation to this. It was first agreed that this theoretical ohm should be represented by the resistance offered to an unvarying current of electricity by a column of mercury one square millimetre in cross section, and one hundred and six centimetres in length, at a definite temperature. Even at the time of the acceptance of this ohm it was well known that the length of this column was nearly three millimetres too small to correctly represent the ohm of the British Association Committee. This result had been established by investigations by Rowland in this country, and by other experimentalists in Europe. In consequence of the inaccuracy of this first material representation of the ohm it did not meet with much favor, although it was quickly taken up among practical men, and resistance coils in great numbers were wound in accordance with this definition, being generally, but incorrectly, known as the 'Legal Ohm.' I do not know that this unit was ever adopted by any government, or even by any municipal corporation.

During the last ten years there has been a continual agitation of this question, resulting in the determination to go over the whole subject again, with a view to defining the fundamental units and adding such other units as might be desirable and necessary, at an International Congress to be held at Chicago in 1893, in connection with the World's Fair. The inception and organization of this Congress was largely due to the American Institute of Electrical Engineers and to local societies in the city of Chicago. Its history is so well known that it is only necessary to refer to it very briefly. In order to avoid errors which are likely to arise in the consideration of a very important subject by a very large assemblage, it was agreed that the question of units should be referred to a body which was within, and formed a part of, the general International Congress, and which was known as the Chamber of Delegates. In this Chamber of Delegates the number of representatives from the different nations was limited; five each were allotted to the United States, Great Britain, France and Germany, three to Italy, and to the other nations a smaller number. Most of the principal delegations were full on the assembling of the Chamber, and the total number of persons was about thirty. Daily sessions were held during the week of the International Congress, and many hours aside from these sessions were occupied by special committees in the discussion and development of the various subjects which came before the Chamber to be acted upon.

In reference to the personnel of this Chamber, it may be well to say that the delegates from foreign countries were appointed by their respective governments and presented regular authenticated commissions, and that the representatives of the United States received their authority from the Secretary of State in a commission which he prepared after the names of the five persons selected had been recommended to him by a vote of about sixty or seventy of the leading electricians of the country, who had been invited to join in this ballot by the Chairman of the Executive Committee for the organization of an International Congress. The five names receiving the greatest number of votes were recommended to the Secretary of State for appointment as representatives of the United States. A list of the delegates present and taking an active part in the deliberation of the Chamber is given herewith:

Representing the United States.

Professor H. A. Rowland, Johns Hopkins University, Baltimore, Md.

Dr. T. C. Mendenhall, Superintendent United States Coast and Geodetic Survey, and of Standard Weights and Measures, Washington, D. C.

Professor H. S. Carhart, University of Michigan, Ann Arbor, Mich.

Professor Elihu Thomson, Lynn, Mass.

Dr. E. L. Nichols, Cornell University, Ithaca, N. Y.

Representing Great Britain.

W. H. Preece, F. R. S., Engineer in Chief and Electrician, Post-office, England; President of the Institution of Electrical Engineers, London.

W. E. Ayrton, City and Guilds of London Central Institution, Exhibition Road, London.

Professor Silvanus P. Thompson, D. Sc., F. R. S., Principal of the City and Guilds Technical College, Finsbury, London.

Alex. Siemens, 12 Queen Anne's Gate, Westminster, London, S. W.

Representing France.

E. Mascart, Membre de l'Institut, 176 rue de l'Université, Paris.

T. Violle, Professeur au Conservatoire des Arts et Metiers, 89 Boulevard St. Michel, Paris.

De la Touanne, Telegraph Engineer of the French Government, 13 rue Soufflot, Paris.

Edouard Hospitalier, Professor a l'École de physique et de chimie industrielle de la ville de Paris; Vice-President de la Societe internationale des Electriciens, 6 rue de Clichy, Paris.

Dr. S. Leduc, 5 quai Fosse, Nantes.

Representing Italy.

Comm. Galileo Ferraris, Professor of Technical Physics and Electro-technics in the R. Museo Industriale, Turin, Via Venti Settembre, 46.

Representing Germany.

H. E. Hermann von Helmholtz, Präsident der Physikalisch-technischen Reichsanstalt, Professor, a. d. Universität, Berlin, Charlottenburg bei Berlin.

Dr. Emil Budde, Berlin N. W. Klopstockstrasse 53.

A. Schrader, Regierungsrath, Mitglied des Kaiserl. Patentamts, Berlin.

Dr. Ernst Voit, Professor an der technischen Hochschule, München, Schwanthalerstrasse, 73-3.

Dr. Otto Lummer, Mitglied der Physikalisch-technischen Reichsanstalt, Charlottenburg, Berlin.

Representing Mexico.

Augustin W. Chavez, City of Mexico.

Representing Austria.

Dr. Johann Sahulka, Technische Hochschule, Wien.

Representing Switzerland.

A. Palaz, Professeur, Lausanne.
René Thury, ingenieur, Florissant, Genève.

Representing Sweden.

M. Wennman, Byrachef i Rougle Telegrafstyrelsen, Stockholm.

Representing British North America.

Ormond Higman, Electrician, Standards Branch, Inland Revenue Department, Ottawa.

As a result of the deliberation of this Chamber, it was agreed to recommend to the several governments represented by the various delegations the adoption of eight units of electrical measure, namely: the ohm, the ampere, the volt, the coulomb, the farad, the joule, the watt and the henry. The Chamber also prescribed definitions for these several units, but as they are essentially the same as those adopted by Congress, and which will be found in detail below, it is not necessary to refer to them here.

Shortly after the adjournment of the Congress a report of its proceedings was made to the Secretary of State by the United States delegates, and this report was distributed by the Department of State among the various nations represented, and also among those not represented, with the request that they should coöperate with the United States in the legalization of the units of electrical measure thus carefully selected and defined. In order to secure action on the part of our own Government, a bill was prepared and introduced into the House of Representatives by Mr. Charles W. Stone, of Pennsylvania, early in 1894, defining these units substantially in agreement with the definitions adopted by the Chamber of Delegates at Chicago, and declaring them to be the legal units of electrical measure for the whole of the United States. Through the active interest of Mr. Stone, and by the assistance of the American Institute of Electrical Engineers or a few individual members thereof who interested themselves in the passage of the measure, this bill became a law by the approval of the President on the 12th of July last.

The differences between the definitions adopted by the International Congress at Chicago and those found in this law are very slight, and consist entirely of verbal changes that were thought to be desirable and necessary by the Senate Committee to which this bill was referred after its passage by the House of Representatives. It may be well to remark that a subcommittee of the Chamber of Delegates, consisting of von Helmholtz, Professor Ayrton and Professor Carhart, had been appointed to prepare specifications for the better realization of the adopted material representation of the volt. The continued illness of von Helmholtz, from the time of his leaving this country, at the close of this Congress, up to the day of his lamented death, about a year later, prevented the completion of the labors of this committee at an earlier date; however, correspondence had been begun, and many points had been defined and settled among its members. The specifications for the better representation of the ampere to which the Chamber of Delegates had agreed will be found in the report of the American delegates to the Secretary of State. As this subcommittee had not yet been able to formulate a report, and as it was necessary for Congress to make some reference to these specifications in the Act adopting the units, it was agreed that the matter should be referred to the National Academy of Science, as is provided in the last section of the Act. This Act, as it finally became a law, is as follows:

(PUBLIC No. 105.)

An Act to define and establish the units of electrical measure.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after the passage of this Act the legal units of electrical measure in the United States shall be as follows:

First. The unit of resistance shall be what is known as the international ohm, which is substantially equal to one thousand million units of resistance of the centimetre-gramme-second system of electro-magnetic units, and represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice fourteen and four thousand five hundred and twenty-one ten thousandths grammes in mass, of a constant cross sectional area, and of the length of one hundred and six and three tenths centimetres.

Second. The unit of current shall be what is known as the international ampere, which is one-tenth of the unit of current of the centimetre-gramme-second system of electro-magnetic units, and is the practical equivalent of the unvarying current, which, when passed through a solution of nitrate of silver in water in accordance with standard specifications, deposits silver at the rate of one thousand one hundred and eighteen millionths of a gramme per second.

Third. The unit of electro-motive force shall be what is known as the international volt, which is the electro-motive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of an international ampere, and is practically equivalent to one thousand fourteen hundred and thirty-fourths of the electro-motive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of fifteen degrees centigrade, and prepared in the manner described in the standard specifications.

Fourth. The unit of quantity shall be what is known as the international coulomb, which is the quantity of electricity transferred by a current of one international ampere in one second.

Fifth. The unit of capacity shall be what is known as the international farad, which is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity.

Sixth. The unit of work shall be the joule, which is equal to ten million units of work in the centimetre-gramme-second system, and which is practically equivalent to the energy expended in one second by an international ampere in an international ohm.

Seventh. The unit of power shall be the watt, which is equal to ten million units of power in the centimetre-gramme-second system, and which is practically equivalent to the work done at the rate of one joule per second.

Eighth. The unit of induction shall be the henry, which is the induction in a circuit when the electromotive force induced in this circuit is one international volt while the inducing current varies at the rate of one ampere per second.

SEC. 2. That it shall be the duty of the National Academy of Sciences to prescribe and publish, as soon as possible after the passage of this Act, such specifications of details as shall be necessary for the practical

application of the definitions of the ampere and the volt hereinbefore given, and such specifications shall be the standard specifications herein mentioned.

Approved July 12, 1894.

It will be desirable to add some remarks upon the steps which have been taken in the same direction by the English Government since the adjournment of the International Congress. All who are familiar with the legislation in the United States on the subject of Weights and Measures will recognize the passage of the Act given above as the first general legislation establishing units of measure for the whole country, on the part of the American Congress.

Although the Constitution provides that Congress shall have the power to establish systems of weights and measures, it is well known that Congress has never exercised this power except in the Act of 1866, which involves the semi-establishment of such a system by making the use of the Metric System permissive throughout the United States. Aside from this, systems of weights and measures in this country have been uniformly and universally the result of State legislation until the passage of the above Act defining units of electrical measure.

In England a committee has for some time been in existence whose object was the recommendation of suitable units of electrical measure, that they might be legalized, as is the practice in Great Britain, by means of an 'Order in Council' signed by the Queen. Among the members of this committee are such well known names as Lord Kelvin, Preece, Glazebrook and Ayrton. This committee made a report on the 2d of August, 1894, and this report was approved by the Queen on the 23d of the same month, so that in this country we were a little more than a month in advance of Great Britain in the legalization of units of electrical measure. The English committee, however, did not feel prepared to go as far as we have gone in the recommendation for the adoption of the whole list of eight units approved at Chicago. Some members of this committee have explained this in personal conference by the statement that the three primary units, the ohm, the ampere and the volt, were found to be not difficult of material representation, while most of the others were very decidedly so, and, as most of the others are derived from these three, it was thought best, at the present time, to restrict authoritative adoption to the ohm, the ampere and the volt. In defining these units the English committee has also departed slightly from the definitions as adopted at Chicago, the changes being mostly verbal, but, in one or two instances, of such a character as to quite alter the fundamental relation of the materialized unit to its theoretical representative. In order that this may be clearly seen, it may be well to quote the definitions of these three units, as found in the 'Order in Council' of August 23d. The following is quoted directly from said 'Order':

"And whereas it has been made to appear to the Board of Trade that new denominations of standards are required for use in trade based upon the following units of electrical measurement, viz.:

"*First.* The Ohm, which has the value of 10^9 in terms of the centimetre and the second of time and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14.4521 grammes in a mass of a constant cross sectional area and of a length of 106.3 centimetres.

"*Second.* The Ampere, which has the value $\frac{1}{10}$ in terms of the centimetre, the gramme and the second of time, and which is represented by the unvarying electric current which, when passed through a solution of nitrate of silver in water, in accordance with the specification appended hereto

and marked A, deposits silver at the rate of 0.001118 of a gramme per second.

"*Third.* The Volt, which has the value of 10^8 in terms of the centimetre, the gramme and the second of time, being the electrical pressure that if steadily applied to a conductor whose resistance is one ohm will produce a current of one ampere, and which is represented by .6974 ($\frac{1000}{1434}$) of the electrical pressure at a temperature of fifteen degrees C. between the poles of the voltaic cell known as Clark's cell, set up in accordance with the specification appended hereto and marked B."

The specifications referred to in the above as marked A are those that were adopted at the Chicago Congress, together with some additional suggestions as to the methods of procedure.

The specification marked B refers to the method of preparation of Clark's cell, including a detailed statement as to materials and as to the method of setting up the cells. These specifications are made so as to include several different kinds of cells, so that the Lord Rayleigh modification of the Clark cell, and also a modification devised and used by the Germans, may be used at will. There is certainly a decided advantage in this. Attached to the 'Order in Council' is a schedule which is declared to set forth the several denominations of electrical standards as approved by the Queen. In this schedule the standard of electrical resistance is described as being the resistance between the copper terminals of a particular coil of wire under standard conditions. The standard of current is described as being the current which when passed through the coils forming a part of a particular instrument under specific conditions gives rise to forces which are exactly balanced by the force of gravity at Westminster upon a particular mass of matter forming a part of said instrument. The standard of electro-motive force, or, as it is termed in the 'Order in Council,' 'electrical pressure,' which is denominated as one volt, is described as being $\frac{1}{100}$ part of the pressure which when applied between the terminals of a particular instrument causes the rotation of a certain portion of said instrument to the extent which is measured by the coincidence of a certain wire with the image in the eyepiece of the telescope and with certain fiducial marks.

A careful examination of the above definitions, together with the schedule following, and a comparison of the same with the units as defined by Act of Congress, which are essentially those of the Chicago Chamber of Delegates, will give rise to many interesting and important reflections to which space cannot now be given. It may be suggested, however, that there is room for uncertainty under the provisions of the English regulations as to what is the standard of resistance, or of current, or of electro-motive force. Of course this will all turn upon what would be the action of the English authorities in case of a suspected error in the material representation of these standards as provided for in the schedule. The 'Order in Council' makes no provision for a course of procedure in such an event, and it is but natural to assume that standards of a very complicated character, and so composite in material as those thus adopted, must be continually liable to changes, and the reintroduction of errors of considerable magnitude.

The actual material representations of these three electrical units, it will be observed, are by this 'Order' removed at a considerable distance from the fundamental definitions adopted by the English committee, as well as by the Chicago Chamber of Delegates, thus, although the ohm is defined primarily by reference to the C. G. S. system of units, and secondarily by reference to the column of mercury, in actual practice it is neither the one nor the other

of these, but is the resistance of a solid metallic conductor.

The ampere, while defined primarily in terms of the C. G. S. system, and secondarily in reference to the silver voltameter, is in practice determined by the dynamic action of one current upon another. In the same way, the volt is not in practice referred to the C. G. S. system of units, nor is it determined by comparison with the Clark cell, but by the measurement of the rotation effect upon a part of a certain instrument when the electro-motive force is applied between certain points in that instrument.

One cannot refrain from the opinion that, from an absolutely metrological standpoint, the regulations of the 'Order in Council' should be condemned rather than approved; however, personal conference with the representatives of the English Board of Trade and Standardizing Laboratory reveals the fact that the material representations of electrical units, thus provided, are to be considered as but tentative in character, adopted on account of greater convenience in actual practice, and to be continually revised and corrected by reference to the fundamental definitions, which are essentially the same as those approved by the representatives of Great Britain at the Chicago Congress, and where they do differ from those are, it will be generally admitted, I think, on the whole, more sound.

It is very important for the United States that, when the time shall come, as it must before long, for the preparation of material representations of as many of the electrical units that have been legalized as can conveniently be represented, the greatest effort shall be made to see that there be no hasty action, and that, as far as possible, already well established principles of metrology shall be strictly applied.

T. C. MENDENHALL.

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THE HUMANITIES.

THE study of the history of mankind is logically developed into five great branches, viz.: industries, pleasures, languages, institutions and opinions. These are the *Humanities.* Into all of these realms modern scientific research penetrates and seeks to discover their origin and development from the beginning of primeval human life to the present time. In following the course of humanity from the earliest savagery to the highest enlightenment it is found that man has traveled by five parallel roads from the starting place of ignorance toward the goal of wisdom. Now he travels on one road, now on another, parceling out his activities and dividing his time between all. On wings of thought he passes from way to way. When he travels by one road he seems to have one end in view, by another road another end in view, and yet as often as he may change his goal and the road by which he travels he is pursuing the route to wisdom. He may travel by false charts, or he may lose his way, and yet the end in view may remain the same. He engages in the arts of industry and the purpose is welfare; he engages in the arts of pleasure and the purpose is happiness; he engages in the arts of speech and the purpose is expression; he engages in institutional arts and the purpose is justice; he engages in the arts of learning and the purpose is knowledge. In the way by labor, the way by pleasure, the way by speech, the way by institutions and the way by learning—in all ways—he runs to the goal of wisdom.

In all the research prosecuted during the present century, and especially during the later decades, one great generalization is reached from the multitudinous facts gathered from the world; this is the intellectual unity of the human race. The history of the lower animals, from primeval geologic time to the present, exhibits a constant differentiation of species, genera, orders and